

CLAIMS

1-14. (canceled)

15. (new) Apparatus for generating a delayed output digital audio signal from an input digital audio signal, the apparatus comprising:

a first delay module adapted to apply a first amount of delay to the input digital audio signal to generate a partially delayed digital audio signal, wherein the first delay module is adapted to select the first amount of delay from a plurality of available first delay values separated from one another by increments at a first resolution level; and

a second delay module adapted to apply a second amount of delay to the partially delayed digital audio signal to generate the delayed output digital audio signal, wherein the second delay module is adapted to select the second amount of delay from a plurality of available second delay values separated from one another by increments at a second resolution level different from the first resolution level.

16. (new) The invention of claim 15, wherein the total range of the plurality of available second delay values at the second resolution level is substantially equal to each increment at the first resolution level.

17. (new) The invention of claim 15, wherein the first delay module comprises:
a buffer adapted to receive and store a plurality of digital values corresponding to the input digital audio signal such that each position in the buffer corresponds to a different one of the plurality of available first delay values; and

a switch having a plurality of input ports and an output port, wherein:
each input port is connected to receive a different digital value stored in the buffer; and
the switch is adapted to present one of the received digital values at its output port based on a first delay control signal.

18. (new) The invention of claim 17, wherein the buffer is a first-in, first-out (FIFO) buffer adapted to receive a new digital value in the input digital audio signal at each clock cycle of the FIFO buffer.

19. (new) The invention of claim 15, wherein the second delay module comprises:
a plurality of digital filters, configured in parallel, each digital filter adapted to apply a different one of the plurality of available second delay values; and
switch circuitry adapted to select, based on a second delay control signal, one of the digital filters to provide the second amount of delay.

20. (new) The invention of claim 19, wherein the digital filters are all-pass filters having different phase shift values.

21. (new) The invention of claim 19, wherein the switch circuitry comprises an input switch adapted to receive and forward the partially delayed digital audio signal to only the selected digital filter.

22. (new) The invention of claim 21, wherein the switch circuitry further comprises an output multiplexer having a plurality of input ports and an output port, wherein:
each input port is connected to a different digital filter; and
the output multiplexer is adapted to present the output from the selected digital filter at its output port.

1 23. (new) The invention of claim 15, further comprising a control module adapted to
2 generate first and second delay control signals used by the first and second delay modules to select the
3 first and second amounts of delay.

1 24. (new) The invention of claim 23, wherein:
2 the control module comprises a look-up table (LUT) storing data that maps 3D positions to
3 interaural delays; and
4 the control module is adapted to:
5 receive a specified 3D position value;
6 retrieve a corresponding interaural delay value from the LUT based on the specified 3D
7 position value; and
8 generate the first and second delay control signals on the retrieved interaural delay value.

1 25. (new) The invention of claim 15, wherein:
2 the first delay module is a coarse delay module having a coarse resolution level; and
3 the second delay module is a fine delay module having a fine resolution level that is finer than
4 the coarse resolution level.

1 26. (new) The invention of claim 25, wherein the first and second amounts of delay are
2 applied to the input digital audio signal to create a relative delay between the delayed output digital audio
3 signal and a second digital audio signal.

1 27. (new) The invention of claim 26, wherein the delayed output and second digital audio
2 signals are left and right ear signals.

1 28. (new) The invention of claim 26, wherein the coarse delay module is adapted to
2 generate the second digital audio signal by delaying the input digital audio signal by a coarse delay value.

1 29. (new) The invention of the claim 28, wherein the coarse delay value used to generate the
2 second digital audio signal is different from the first amount of delay used to generate the partially
3 delayed digital audio signal.

1 30. (new) The invention of the claim 15, further comprising a control module adapted to
2 generate first and second delay control signals used by the first and second delay modules to select the
3 first and second amounts of delay, wherein:

4 the first delay module comprises:
5 a buffer adapted to receive and store a plurality of digital values corresponding to the
6 input digital audio signal such that each position in the buffer corresponds to a different one of the
7 plurality of available first delay values; and

8 a switch having a plurality of input ports and an output port, wherein:
9 each input port is connected to receive a different digital value stored in the
10 buffer; and

11 the switch is adapted to present one of the received digital values at its output
12 port based on the first delay control signal;

13 the second delay module comprises:
14 a plurality of digital filters, configured in parallel, each digital filter adapted to apply a
15 different one of the plurality of available second delay values; and
16 switch circuitry adapted to select, based on the second delay control signal, one of the
17 digital filters to provide the second amount of delay; and

18 the total range of the plurality of available second delay values at the second resolution level is
19 substantially equal to each increment at the first resolution level.

1 31. (new) The invention of claim 30, wherein:
2 the buffer is a FIFO buffer adapted to receive a new digital value in the input digital audio signal
3 at each clock cycle of the FIFO buffer;
4 the digital filters are all-pass filters having different phase shift values;
5 the switch circuitry comprises:
6 an input switch adapted to receive and forward the partially delayed digital audio signal
7 to only the selected digital filter; and
8 an output multiplexer having a plurality of input ports and an output port, wherein:
9 each input port is connected to a different digital filter; and
10 the output multiplexer is adapted to present the output from the selected digital
11 filter at its output port;
12 the control module comprises a LUT storing data that maps 3D positions to interaural delays; and
13 the control module is adapted to:
14 receive a specified 3D position value;
15 retrieve a corresponding interaural delay value from the LUT based on the specified 3D
16 position value; and
17 generate the first and second delay control signals on the retrieved interaural delay value.

1 32. (new) The invention of claim 30, wherein:
2 the first delay module is a coarse delay module having a coarse resolution level;
3 the second delay module is a fine delay module having a fine resolution level that is finer than
4 the coarse resolution level;
5 the first and second amounts of delay are applied to the input digital audio signal to create a
6 relative delay between the delayed output digital audio signal and a second digital audio signal;
7 the delayed output and second digital audio signals are left and right ear signals;
8 the coarse delay module is adapted to generate the second digital audio signal by delaying the
9 input digital audio signal by a coarse delay value;
10 the coarse delay value used to generate the second digital audio signal is different from the first
11 amount of delay used to generate the partially delayed digital audio signal.

1 33. (new) A method for generating a delayed output digital audio signal from an input
2 digital audio signal, the method comprising:
3 (a) applying a first amount of delay to the input digital audio signal to generate a partially
4 delayed digital audio signal, wherein the first amount of delay is selected from a plurality of available
5 first delay values separated from one another by increments at a first resolution level; and
6 (b) applying a second amount of delay to the partially delayed digital audio signal to
7 generate the delayed output digital audio signal, wherein the second amount of delay is selected from a
8 plurality of available second delay values separated from one another by increments at a second
9 resolution level different from the first resolution level.

1 34. (new) The invention of claim 33, wherein the total range of the plurality of available
2 second delay values at the second resolution level is substantially equal to each increment at the first
3 resolution level.

1 35. (new) The invention of claim 33, wherein step (a) comprises:
2 receiving and storing, in a buffer, a plurality of digital values corresponding to the input digital
3 audio signal such that each position in the buffer corresponds to a different one of the plurality of
4 available first delay values; and
5 selecting, based on a first delay control signal, one of the stored digital values as the partially
6 delayed digital audio signal.

1 36. (new) The invention of claim 35, wherein the buffer is a FIFO buffer adapted to receive
2 a new digital value in the input digital audio signal at each clock cycle of the FIFO buffer.

1 37. (new) The invention of claim 33, wherein step (b) comprises:
2 selecting, based on a second delay control signal, one of a plurality of digital filters, configured
3 in parallel, each digital filter adapted to apply a different one of the plurality of available second delay
4 values; and
5 delaying the partially delayed digital audio signal using the selected digital filter to provide the
6 second amount of delay.

1 38. (new) The invention of claim 37, wherein the digital filters are all-pass filters having
2 different phase shift values.

1 39. (new) The invention of claim 33, further comprising (c) generating first and second
2 delay control signals used in steps (a) and (b) to select the first and second amounts of delay.

1 40. (new) The invention of claim 39, wherein step (c) comprises:
2 receiving a specified 3D position value;
3 retrieving, based on the specified 3D position value, a corresponding interaural delay value from
4 a LUT storing data that maps 3D positions to interaural delays; and
5 generating the first and second control signals based on the retrieved interaural delay value.

1 41. (new) The invention of claim 33, wherein the first amount of delay is larger than the
2 second amount of delay.

1 42. (new) The invention of claim 41, wherein the first and second amounts of delay are
2 applied to the input digital audio signal to create a relative delay between the delayed output digital audio
3 signal and a second digital audio signal.

1 43. (new) The invention of claim 42, wherein the delayed output and second digital audio
2 signals are left and right ear signals.

1 44. (new) The invention of claim 42, wherein a coarse delay value is applied to the input
2 digital audio signal to generate the second digital audio signal.

1 45. (new) The invention of the claim 44, wherein the coarse delay value used to generate the
2 second digital audio signal is different from the first amount of delay used to generate the partially
3 delayed digital audio signal.

1 46. (new) The invention of claim 33, further comprising (c) generating first and second
2 delay control signals used in steps (a) and (b) to select the first and second amounts of delay, wherein:
3 step (a) comprises:

4 receiving and storing, in a buffer, a plurality of digital values corresponding to the input
5 digital audio signal such that each position in the buffer corresponds to a different one of the plurality of
6 available first delay values; and

7 selecting, based on a first delay control signal, one of the stored digital values as the
8 partially delayed digital audio signal;

9 step (b) comprises:

10 selecting, based on a second delay control signal, one of a plurality of digital filters,
11 configured in parallel, each digital filter adapted to apply a different one of the plurality of available
12 second delay values; and

13 delaying the partially delayed digital audio signal using the selected digital filter to
14 provide the second amount of delay; and

15 the total range of the plurality of available second delay values at the second resolution level is
16 substantially equal to each increment at the first resolution level.

1 47. (new) The invention of claim 46, wherein:

2 the buffer is a FIFO buffer adapted to receive a new digital value in the input digital audio signal
3 at each clock cycle of the FIFO buffer;

4 the digital filters are all-pass filters having different phase shift values; and

5 step (c) comprises:

6 receiving a specified 3D position value;

7 retrieving, based on the specified 3D position value, a corresponding interaural delay
8 value from a LUT storing data that maps 3D positions to interaural delays; and

9 generating the first and second control signals based on the retrieved interaural delay
10 value.

1 48. (new) The invention of claim 46, wherein:

2 the first amount of delay is larger than the second amount of delay;

3 the first and second amounts of delay are applied to the input digital audio signal to create a
4 relative delay between the delayed output digital audio signal and a second digital audio signal;

5 the delayed output and second digital audio signals are left and right ear signals;

6 a coarse delay value is applied to the input digital audio signal to generate the second digital
7 audio signal;

8 the coarse delay value used to generate the second digital audio signal is different from the first
9 amount of delay used to generate the partially delayed digital audio signal.

1 49. (new) An apparatus for generating a delayed output digital audio signal from an input
2 digital audio signal, the apparatus comprising:

3 (a) means for applying a first amount of delay to the input digital audio signal to generate a
4 partially delayed digital audio signal, wherein the first amount of delay is selected from a plurality of
5 available first delay values separated from one another by increments at a first resolution level; and

6 (b) means for applying a second amount of delay to the partially delayed digital audio signal
7 to generate the delayed output digital audio signal, wherein the second amount of delay is selected from a
8 plurality of available second delay values separated from one another by increments at a second
9 resolution level different from the first resolution level.